Rip Currents

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LONG TERM GOAL

To examine the dynamics of rip currents and the factors governing the evolution and magnitude of the cross-shore fluxes of sediment and water associated with rip cell circulation on a medium to high energy beach over a wide range of space and time scales.

OBJECTIVES

Scientific

- To examine the spatial and temporal variability of rip currents using remote video imaging techniques.
- To quantify changes in nearshore circulation and topography in response to varying incident wave conditions at different time scales including;
  - wave groupiness (time scales of 1-10 minutes),
  - tidal modulation (time scales of 12h and 24 h) and
  - wave height fluctuations associated with passing weather systems (time scales of 2-5 days).
- To develop a coupled hydrodynamic and sediment transport model to simulate the coupling between the nearshore circulation forced by the incident wave field, and the nearshore topography.

Technical

- To advance current nearshore video imaging techniques using a high resolution digital camera system.

APPROACH

Video techniques can be used in three possible ways in our studies;

(i) In principle the video images can be used to build up a statistical description of rip cells including longshore and cross-shore length scales, persistence, surf zone width and some incident wave information (period and direction). It remains to develop an automated approach to obtaining some of these rip cell statistics.

(ii) Fluctuations of the head can be measured through video time stacks and should provide a good proxy for the fluctuating strength of the rip current. Preliminary results using 15 minute time sequences of shorter time exposures (of order one minute) have shown at least one example in which the entire rip head can be observed to expand offshore.

(iii) It may be possible to use the offshore advection of foam (or other visible features) to estimate actual rip current velocities. A similar approach, based on time stacks, for the estimation of longshore current velocities appears quite promising. Testing of this approach is a research goal of this work.

We also aim to combine the video images with numerical simulations to investigate the spatial and temporal variability of rip currents in response to changing incident wave conditions and sea level fluctuations. For example, tidal modulation of rip currents has been discussed by Shepard et al (1941), Sonu (1972) and Short and Hogan (1994). Theoretical considerations suggest the magnitude of onshore flow over the bar due to wave pumping depends on the relative magnitudes of incident wave height and depth over the bar which in turn varies with tidal elevation. We will examine tidal modulation of currents and setup numerically, while variability in rip current intensity may be quantified using the video techniques outlined above.

WORK COMPLETED

From two years of video images we have extracted daily time series of mean surf zone width and longshore profiles of intensity averaged across the surf zone. . Preliminary results are described by Ranasinghe et al (1999) and a more detailed description of the methods and results has been completed and submitted to the Journal of Geophysical Research. In addition to the image analysis a new model for rip current generation on a plane beach has been developed and a manuscript has been submitted to the Journal of Geophysical Research.

A two dimensional, depth integrated numerical model with radiation stress forcing is being used to model rip circulation over prescribed topography, and a coupled sediment transport model is being used to simulate the morphological evolution inferred from the video time exposure images. Using the video images the morphology can be classified according to the four intermediate beach states identified by Wright and Short (1984). One aim of the modelling effort is to simulate the transition from one state to another and, while the model is still in the process of being tested, preliminary results have been encouraging.

In October 1999, a field program was undertaken to obtain in situ measurements of rip currents on Palm Beach, as part of a closely related project funded by the Australian Research Council. We are attempting to obtain continuous measurements of mean currents in a rip channel for a period of order one month with a shorter, more intensive deployment spanning 1-2 tidal cycles. The Palm Beach site was chosen in order to utilise the extensive video coverage available through the Argus station. Holman is participating in this field work using video to sample extensive pixel arrays over the study site similar to what was done during recent expriments at Duck, North Carolina. As part of this work the second Argus camera at Palm Beach has been fitted with a longer 35mm lens and re-aimed to cover the experiment site near the middle of the beach.

RESULTS

Rip spacing and persistence on a swell dominated beach

Historically it has been difficult to observe rip currents on natural beaches due, in part, to the high degree of spatial and temporal variability of the incident wave field and nearshore morphology. Time exposure video images provide a cost-effective means of monitoring the morphological evolution of rip-cells over spatial scales of 10 – 1000m and temporal scales of days to months. In this study, two years of daily time exposure images were used to extract mean longshore intensity profiles which provided quantitative estimates of rip channel location, rip spacing, and rip persistence. This technique provides longer time series and significantly more accurate estimates than was previously possible with visual observations and conventional survey methods.

The probability of rips occurring on Palm Beach was 78%. The observations indicate that rip channels which disappear when storms re-work the nearshore morphology do not re-appear at the same locations in a majority of the cases. In contrast to Short's (1985) findings at Narrabeen Beach, Australia, rip channels do not appear to have preferred locations at Palm Beach.

The observed rip spacings during the entire study period were an order of magnitude larger than the predictions of the rip generation model proposed by Bowen (1969). An unrealistically large directional spread of incident waves (for a swell dominated beach) is required for the mechanism proposed by Dalrymple (1975) to produce rips at the observed spacing. The linear correlation between rip spacing and surf zone width predicted by the rip generation models proposed by Hino (1974), Dalrymple and Lozano (1978), and Miller and Barcillon (1978) was not apparent in the observations. Model predictions of rip spacing compared poorly with observed rip spacing even when the analysis was restricted to periods of initial formation of rips, i.e. immediately after storms. Hence, it is concluded that rip formation on swell dominated beaches is not due to the mechanisms proposed in any of the theoretical models. The results also indicate that rip spacing does not adjust to variations in offshore wave height suggesting that rip currents may be topographically controlled by the underlying shoals and channels once they are formed.

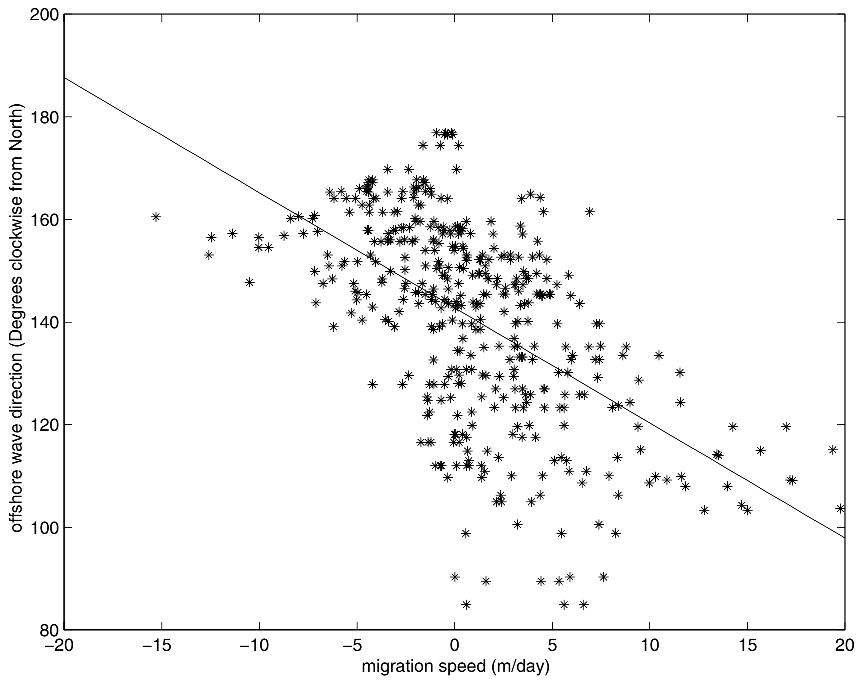

Figure 1
Rip migration speed versus deep water wave direction.

The observations also indicate that rip channels migrate alongshore with speeds of 2 – 20 m/day under obliquely incident waves. Rip mobility does not appear to depend on changes in offshore wave height as suggested by Short (1985). A wave refraction/diffraction model was used to obtain corresponding incident wave angles just seawards of the breakpoint for a range of offshore wave angles. The results suggest that the observed longshore migration of rip channels maybe due to gradients in longshore sediment transport caused by longshore currents driven by obliquely incident waves.

A new model for rip formation on a plane beach
The superposition of normally incident wave groups and an edge wave at the same frequency on a plane beach produces rip currents with a longshore spacing determined by the edge wave dispersion relationship.

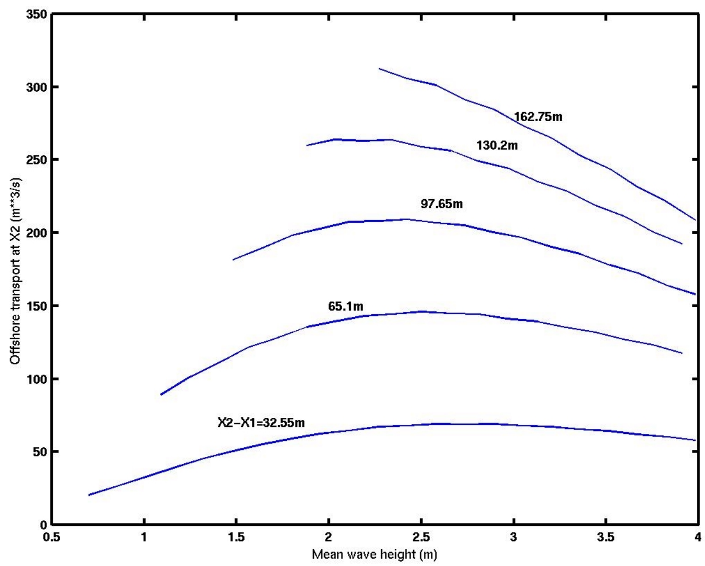

Figure 2
Offshore transport integrated across the rip channel as a function of wave height and breakpoint excursion for the progressive edge wave case.

The cross-shore decay in the edge wave amplitude and the relative phase between the edge wave and the incident wave groups are included in the model. The model differs from Bowen (1969) in two ways.

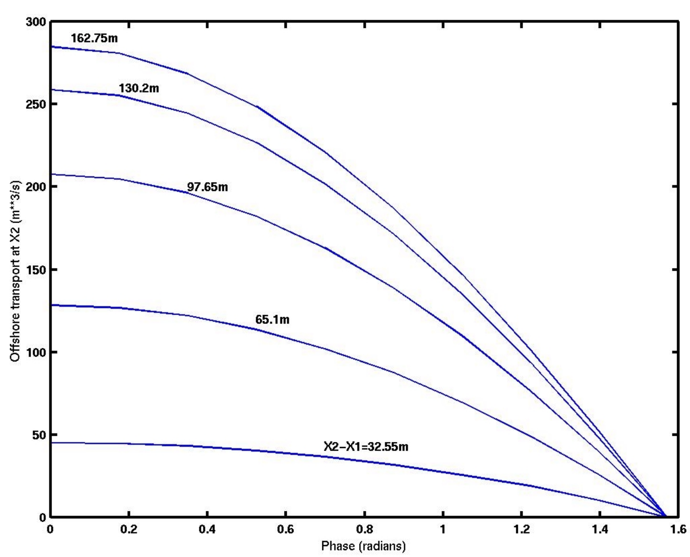

Figure 3
Rip transport as a function of phase between the incident wave groups and a standing edge wave for different breakpoint excursions.

Firstly, the edge wave slowly modulates the total water depth instead of the incident wave height. Secondly, the lower infragravity frequency results in longshore scales one to two orders of magnitude larger than Bowen's model. Solutions for both standing and progressive edge waves have been obtained. For the progressive edge wave case the location of the rip currents depends on the relative phase (θ) between the incident wave groups and the edge wave while the magnitude of the currents depends on the mean incident wave height, the modulation of the wave group and the edge wave amplitude. In the standing edge wave case the location of the rip currents is independent of the phase and, with $\theta = 0$, the solutions are identical to the progressive edge wave case. However, as $\theta \to \pi/2$ the magnitude of the rip circulation decreases to zero.

IMPACT/APPLICATIONS

The recent increase in focus on the littoral environment has pointed out weaknesses in our understanding of nearshore dynamics. While our knowledge of nearshore fluid motions on simple topography has become quite good, such simple cases are actually rare. Most often beaches are three-dimensional leading to longshore and cross-shore variations in wave heights and associated mean flows. The development and evolution of such systems has only been poorly sampled. This work takes advantage of a strong combination of low-cost, data-rich sampling of the Argus program, mixed with modelling skills, to help advance understanding of these ubiquitous fluid/sediment interactions.

The result of this work will help provide environmental understanding of important mean current and topographic variability that is likely to be encountered on natural beaches. This type of understanding is needed for all amphibious operations in nearshore waters on sandy coasts.

TRANSITIONS

Rip currents are the greatest threat to public safety around the Australian coast and are responsible for 10,000's rescues and up to 100 drownings each year. Rips are also the major cause of severe beach erosion and property loss. While the presence of rips is generally well known there remains a gap between the growing scientific understanding of rips and its application in the public domain, both in terms of beach safety and beach erosion. This project will significantly expand our scientific knowledge of rip locations, dynamics and impacts, and transfer this information directly to Surf Life Saving Australia (SLSA) for use in training, beach management and education, as well as to state authorities such as the Department of Land and Water Conservation (DLWC) managing rip-generated beach erosion.

RELATED PROJECTS

1. Rip current dynamics - social and shoreline implications and management
Chief Investigators: Assoc. Prof. A. D. Short, Dr P. Cowell (University of Sydney)
Dr. G. Symonds (University of New South Wales)
Industry Partners: Surf Life Saving Australia
N.S.W Department of Land and Water Conservation
Funding Agency: Australian Research Council, Strategic Partnerships with Industry - Research and Training
Funding:

1999	$90,256
2000	$60,256
2001	$45,256

2. Gold Coast Video Monitoring

In collaboration with Dr. I. Turner (Water Research Laboratory) and Delft Hydraulics an Argus station has been installed on the Gold Coast, Queensland, to monitor a major beach renourishment and the impact of an artificial reef currently under construction. The Argus station contains five cameras providing a 180^0 field of view along the beach. While rip currents are common along this long straight beach the argus images have shown the morphology to be considerably more complicated than Palm Beach. In particular it is a double barred system with rips appearing most often through the inner bar. The shoreline detection technique developed for Palm Beach is being used to monitor shoreline change during and after the renourishment and reef construction.

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